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TECHNICAL REPORT ARLCB-TR-82040

EROSION AND ITS CONTROL

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US ARMY ARMAMENT RESEARCH AND DEVELOPMENT COMMAND
LARGE CALIBER WEAPON SYSTEMS LABORATORY
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WATERVLIET N.Y. 12189

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REPORT DOCUMENTATION PAGE

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1. REPORT NUMBER ARLCB-TR-83040	2. GOVT ACCESSION NO. AD-A123164
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle) EROSION AND ITS CONTROL	5. TYPE OF REPORT & PERIOD COVERED Final
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) R. S. Montgomery and F. K. Sautter	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army Armament Research & Development Command Benet Weapons Laboratory, DRDAR-LCB-TL Watervliet, NY 12189	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS AMCMS No. 611102H600011 DA Project No. 1L161102AH60 PRON No. 1A2250041A1A
11. CONTROLLING OFFICE NAME AND ADDRESS US Army Armament Research & Development Command Large Caliber Weapon Systems Laboratory Dover, NJ 07801	12. REPORT DATE December 1982
	13. NUMBER OF PAGES 16
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	15. SECURITY CLASS. (of this report) UNCLASSIFIED
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

To be presented at Spring Meeting ASLE, Houston, TX, 25-28 April 1983.
To be published in Transactions of ASLE Meeting.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Erosion
Bore Temperature
Temperature Resistance
Propellant Additives

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Gun erosion is a complicated process which involves a number of interrelated factors. There is general agreement that erosion is a function of bore temperature but this does not eliminate controversy about its causes or the relative importance of different factors. The three effects involved in gun erosion are thermal, chemical, and mechanical. In the case of the most important erosion, that of steel bores at the origin-of-rifling, the chief factor is probably

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20. ABSTRACT (CONT'D)

thermal. However, no matter what the specific mechanism of erosion, it is a function of the rate of heat transferred to the bore. It can only be controlled by making the steel bore more resistant to temperature by coating it with a layer of another material or by lowering the rate of heat transfer from the pı ›pellant gases.

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INTRODUCTION

Gun erosion can be defined as the gradual changes in bore dimensions as a result of firing and the changes in character of the bore surface and walls that lead to these changes in dimensions.[1] Therefore the term "erosion", historically applied to guns, refers to dimensional changes and does not imply any particular mechanism.

DISCUSSION

Gun erosion is a complicated process which involves a number of interrelated factors. There is general agreement that erosion is a function of bore temperature. This does not, however, eliminate controversy about its causes or the relative importance of different factors. Some of the disagreement has been due to the fact that the individual factors have different relative importances in different guns, under different firing conditions, and at different locations in the bore.[2]

In general, there are three factors involved in gun erosion, namely:

1. Thermal effects, that is melting or softening of the bore surface, followed by removal.
2. Chemical reaction of the bore surface with the propellant gases.
3. Mechanical effects such as engraving and traction.

Each of these factors is affected by temperature and can be important under some conditions. Their relative importance cannot be inferred from the

[1] L. E. Line, Jr., "The Description of Eroded Gun Bores," Hypervelocity Guns and the Control of Gun Erosion, Washington, D.C., 1946, p. 195.
[2] C. A. Marsh and J. N. Hobstetter, "The Causes of Gun Erosion," Ibid, p. 260.

fact that erosion is a function of bore temperature.

There has been a great deal of research to substantiate the fact that cannon erosion involves bore surface temperature, but we will only discuss a few examples. Vassallo of Calspan Corporation carried out some excellent research on an experimental 75 mm cannon[3] where he obtained a measurement of erosion for different alloys used for the bore. This erosion data can be correlated with the melting points of the alloys.[4] Above a threshold temperature, in this case about 1460°C, erosion is an inverse function to the melting point of the alloy. For alloys with melting points above this threshold, there was no measurable erosion. This is shown in Figure 1. In another work using a uniquely instrumented 60 mm research cannon, a simplified correlation related material loss to the rate of energy generation for steel cannon bores[5] (see Figure 2). Ward, of the Army Ballistic Laboratory, correlated erosion with heat transferred to the gun barrel and evaluated the erosive characteristics of propellants and effectiveness of additives by measuring this heat transfer.[6] This is illustrated by Figure 3 which is taken from Reference 6. There was a threshold heat input below which there

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[3]F. A. Vassallo, "Heat Transfer and Erosion in the ARES 75 MM High Velocity Cannon," Calspan Technical Report No. VL-5645-D-1, 1975.

[4]F. K. Sautter, "The Factors Contributing to Wear and Erosion of a Chrome-Plated Cannon," The Tri-Service Gun Tube Wear and Erosion Symposium, Dover, NJ, 1977.

[5]F. A. Vassallo, "Thermal and Erosion Phenomenology in Medium Caliber Anti-Armor Automatic Cannons (MC-AAC)," JANNAF Propulsion Meeting, Monterey, Ca, 1980.

[6]J. Richard Ward and T. L. Brosseau, "Role of the Insulating Layer From TiO_2-Wax Liner in Reducing Gun Tube Wear," Ibid.

was no measured erosion of the steel. In addition, Marsh and Hobstetter[2] summarizing the research on erosion carried out during World War II, described the effects of increased temperature on the response of the bore metal.

Many of the components of propellant gases react with steel to produce an altered layer on its surface which is lower melting than the metal itself and doubtlessly more easily removed.[1,2,7-9] Caveny[7] stated that in the submelting temperature range, the surface chemical attack of steel is the main erosion source. Various types of steel generally resist the attack of gases such as N_2, CO, and CO_2, but water vapor will vigorously react with all steels and produce erosion. While Caveny is no doubt correct about the importance of chemical reaction in this temperature range, erosion is low here and it is not a problem in this range. Erosion is about 5 μm a round for the Army wear limited cannons[10] and it is difficult to see how a surface chemical reaction could account for much of this with the very short reaction times available.

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[1] L. E. Line, Jr., "The Description of Eroded Gun Bores," Hypervelocity Guns and the Control of Gun Erosion, Washington, D.C., 1946, p. 195.

[2] C. A. Marsh and J. N. Hobstetter, "The Causes of Gun Erosion," Ibid, p. 260.

[7] L. H. Caveny, "Steel Erosion Produced by Water Vapor Containing Chamber Gases," JANNAF Propulsion Meeting, Monterey, CA, 1980.

[8] F. A. Vassallo and E. B. Fisher, "The Role of Oxygen in Gun Barrel Erosion and Cracking," Ibid.

[9] C. C. Morphy and E. B. Fisher, "Gas Chemistry Effects on Gun Barrel Erosion-A Shock Tube Gun Investigation," Contract Report ARBRL-CR-00481, US Army Armament Research and Development Command, 1982.

[10] T. L. Brosseau, I. C. Stobie, and J. Richard Ward, "Interior Ballistic Evaluation of High-Flame Temperature Propellants in 20 MM Ammunition and Assessment as an Erosion Test Device," Army Ballistic Research Laboratory Technical Report ARBRL-TR-02314, 1981.

When the bore metal is steel, purely mechanical effects are probably unimportant in the most important erosion, that at the origin-of-rifling. However, mechanical effects are very important when the bore is covered with a temperature resistant coating such as electroplated chromium and in "muzzle erosion".[11] If the bore does not react significantly with propellant gases and it does not soften or melt, the erosion must be caused by mechanical effects. This is true for chromium electroplate which is high-melting and chemically inert but which is brittle and must withstand the flexing of the steel under it.

Cavitation has been suggested as an important contributer to erosion. However, there was no correlation found between erosion and the known sensitivities of bore metals to cavitation erosion, so it was concluded that cavitation is not important in erosion.[12] In addition, the initial erosion rate is the maximum and an incubation period, such as observed with cavitation erosion, is never observed.[13] The erosive action of unburned powder granules on the softened bore metal has also been postulated to be important. The presence and location of these have been shown to affect heat transfer to the

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[11] R. S. Montgomery, "Muzzle Wear of Cannon," Wear, 33, p. 359, 1975.

[12] L. E. Line, Jr., "Laboratory Methods of Studying Gun Erosion," Hypervelocity Guns and the Control of Gun Erosion, Washington, D.C., 1946, p. 219.

[13] R. S. Montgomery, J. F. Cox, and F. K. Sautter, Comments on "Scaling Laws Governing Gun Erosion," Wear, 43, p. 271, 1977.

bore,[14] but it is difficult to uncouple scouring of unburned granules from the known effect of the scouring of the propellant gases themselves. However, it is our opinion that this effect is not important. It has also been suggested that inadequate obturation of the propellant gases by the projectile bands causes sweeping away of the bore metal at the location of "leaks". While this factor may be of importance in some individual cases, it cannot be important in erosion in general because rifling grooves erode much less than rifling lands.[1] The reverse would be expected if leaks were an important cause of erosion since they always occur at the grooves. In addition, erosion using projectiles with leakage slots milled into their rotating bands was no greater than with ordinary projectiles.[15]

Thermal effects on the bore metal, in our opinion, are generally the most important causes of erosion at the higher temperatures when erosion becomes very important. The effect of temperature on the bore metal is probably influenced by the chemical reaction of the metal with the propellant gases. This is indicated by the somewhat different erosions at the same rates of energy generation caused by different propellants although the different flame temperatures of the propellants certainly cause a complication. See Figure 2.

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[1]L. E. Line, Jr., "The Description of Eroded Gun Bores," Hypervelocity Guns and the Control of Gun Erosion, Washington, D.C., 1946, p. 195.

[14]J. R. Ward, "On the Erosivity of Stick and Granular Propellant," Army Ballistics Laboratory Memorandum Report ARBRL-MR-03171, 1982.

[15]Nicol H. Smith, "Pre-Engraved Projectile With Chrome-Plated Bore," Hypervelocity Guns and the Control of Gun Erosion, Washington, D.C., 1946, p. 591.

No matter what the specific mechanism of gun erosion, it is a function of the rate of heat transferred to the bore. It can be controlled in only two ways.

1. The gun bore can be made more resistant to temperature.

2. The rate of heat transfer from the propellant gases can be lowered.

Because of economic and other considerations a cannon must be made of steel. If additional temperature resistance is desired, it can be coated with a layer of another material on the bore. Only the high-melting metals chromium, tungsten, molybdenum, and tantalum have been shown to have value.[16] Chromium electroplate is being used[17] and coatings of molybdenum,[18] tungsten,[19] and tantalum[20] have been investigated on an experimental basis. This approach has promise although the cost could be high if other than chromium electroplate was used.

If a propellant could be used that had a lower flame temperature, the rate of heat transfer would be lowered and a lower rate of erosion would result. Unfortunately, this approach is of only limited use because of the

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[16]J. F. Schairer, "Selection of Erosion Resistant Materials for Gun Bores," Hypervelocity Guns and the Control of Gun Erosion, Washington, D.C., 1946, p. 331.

[17]J. A. Lannon and A. C. Vallado, "Effect of Chrome Plating on the Wear Characteristics and Ballistic Performance in the 155 MM Artillery System," JANNAF Propulsion Meeting, Monterey, CA, 1980.

[18]F. Palmer, "Molybdenum," Hypervelocity Guns and the Control of Gun Erosion, Washington, D.C., 1946, p. 370.

[19]K. H. Meyer and J. W. Gehring, "A New Technique for Retarding Erosion of Gun Barrels by Plating the Bores With Tungsten," Interservice Technical Meeting on Gun Tube Erosion and Control, Watervliet, NY, 1970.

[20]G. D'Andrea and R. L. Cullinan, "Erosion Study of Tantalum Coated Gun Barrels," JANNAF Propulsion Meeting, Monterey, CA, 1980.

impulse required of the propellant to achieve the desired ballistic characteristics. About all that can be done is to avoid propellants with extremely high flame temperatures.

A very effective means of reducing gun erosion by reducing the rate of heat transfer has been through the use of "additives". These are termed additives although they are not generally additives to the propellant. Often they are in the form of liners in the cartridge case. The original wear-reducing liner was a high-density polyurethane foam glued to the wall of the cartridge case. Soon after the U.S. adopted the polyurethane foam in high-velocity tank guns, a liner was made from a 45/55 percent blend of TiO_2 and paraffin wax and the U.S. adopted this. Figure 4 from Reference 6 shows how these are placed. The original wear life of the tank gun when it was introduced was only 100 rounds when firing a particular high-velocity round. The introduction of polyurethane foam increased this to 400 rounds. Finally the use of the TiO_2-wax liner increased this wear life to 10,000 rounds.[6] (The fatigue life of the tube is much lower than this.) The effectiveness of the liner is extremely affected by its exact placement in the cartridge case. Many of the new projectiles keep the liner from being positioned in the optimum way. In addition, all the large cannons used in the U.S. Army are bag-loaded and do not use cartridge cases. The erosion problems with the large cannon are not as severe as with the tank guns but many of them are

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[6] J. Richard Ward and T. L. Brosseau, "Role of the Insulating Layer From TiO_2-Wax Liner in Reducing Gun Tube Wear," JANNAF Propulsion Meeting, Monterey, CA, 1980.

still limited by their wear lives. Therefore new erosion reducing additives have continued to be studied. A combustible cartridge case containing talc and the so-called ablative additive which is a silicone fluid positioned at the base of the projectile have both shown promise. See Figure 3.

SUMMARY

Gun erosion is a complex phenomenon that is caused by chemical, mechanical, and thermal factors. All of these are affected by thermal environment and erosion can be estimated by measurements of the rate of heat transfer from the propellant gases to the cannon bore. Gun erosion can be controlled by increasing the heat resistance of the bore by using some sort of electroplate or bore liner or by reducing the rate of heat transfer to the bore. Despite the efforts so far, gun erosion remains a serious problem and research is continuing on its control.

REFERENCES

1. L. E. Line, Jr., "The Description of Eroded Gun Bores," Hypervelocity Guns and the Control of Gun Erosion, Washington, D.C., 1946, p. 195.
2. C. A. Marsh and J. N. Hobstetter, "The Causes of Gun Erosion," Ibid, p. 260.
3. F. A. Vassallo, "Heat Transfer and Erosion in the ARES 75 MM High Velocity Cannon," Calspan Technical Report No. VL-5645-D-1, 1975.
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5. F. A. Vassallo, "Thermal and Erosion Phenomenology in Medium Caliber Anti-Armor Automatic Cannons (MC-AAC)," JANNAF Propulsion Meeting, Monterey, CA, 1980.
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8. F. A. Vassallo and E. B. Fisher, "The Role of Oxygen in Gun Barrel Erosion and Cracking," Ibid.
9. C. C. Morphy and E. B. Fisher, "Gas Chemistry Effects on Gun Barrel Erosion - A Shock Tube Gun Investigation," Contract Report ARBRL-CR-00481, US Army Armament Research and Development Command, 1982.

10. T. L. Brosseau, I. C. Stobie, and J. Richard Ward, "Interior Ballistic Evaluation of High-Flame Temperature Propellants in 20 MM Ammunition and Assessment as an Erosion Test Device," Army Ballistic Research Laboratory Technical Report ARBRL-TR-02314, 1981.

11. R. S. Montgomery, "Muzzle Wear of Cannon," Wear, 33, p. 359, 1975.

12. L. E. Line, Jr., "Laboratory Methods of Studying Gun Erosion," Hypervelocity Guns and the Control of Gun Erosion, Washington, D.C., 1946, p. 219.

13. R. S. Montgomery, J. F. Cox, and F. K. Sautter, Comments on "Scaling Laws Governing Gun Erosion," Wear, 43, p. 271, 1977.

14. J. R. Ward, "On the Erosivity of Stick and Granular Propellant," Army Ballistics Laboratory Memorandum Report ARBRL-MR-03171, 1982.

15. Nicol H. Smith, "Pre-Engraved Projectile With Chrome-Plated Bore," Hypervelocity Guns and the Control of Gun Erosion, Washington, D.C., 1946, p. 591.

16. J. F. Schairer, "Selection of Erosion Resistant Materials for Gun Bores," Ibid, p. 331.

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18. F. Palmer, "Molybdenum," Hypervelocity Guns and the Control of Gun Erosion, Washington, D.C., 1946, p. 370.

19. K. E. Meyer and J. W. Gehring, "A New Technique for Retarding Erosion of Gun Barrels by Plating the Bores With Tungsten," Interservice Technical Meeting on Gun Tube Erosion and Control, Watervliet, NY, 1970.

20. G. D'Andrea and R. L. Cullinan, "Erosion Study of Tantalum Coated Gun Barrels," JANNAF Propulsion Meeting, Monterey, CA, 1980.

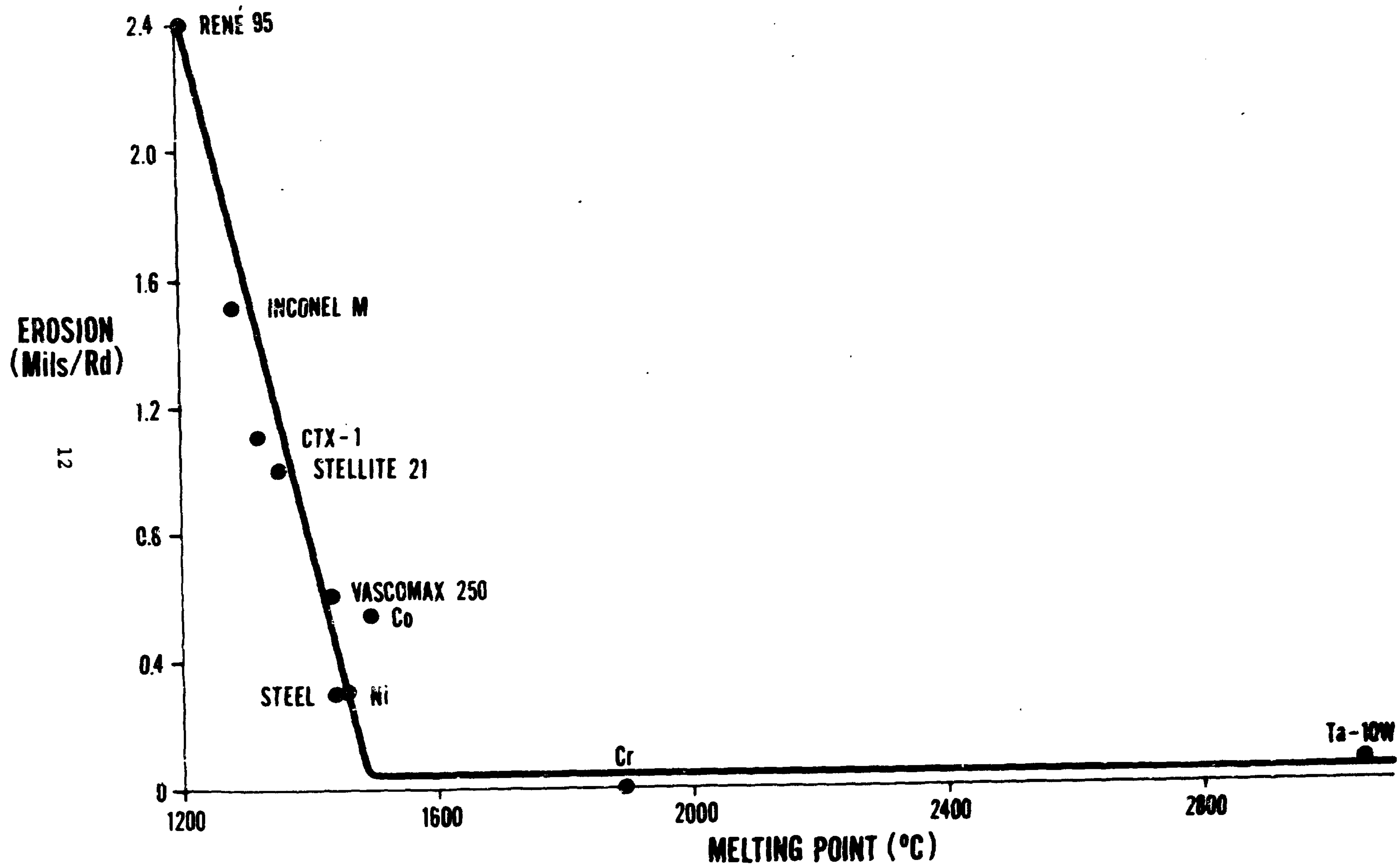

Figure 1. Effect of Bore Metal Melting Point on Erosion Based on Weight Loss (data from Reference 3).

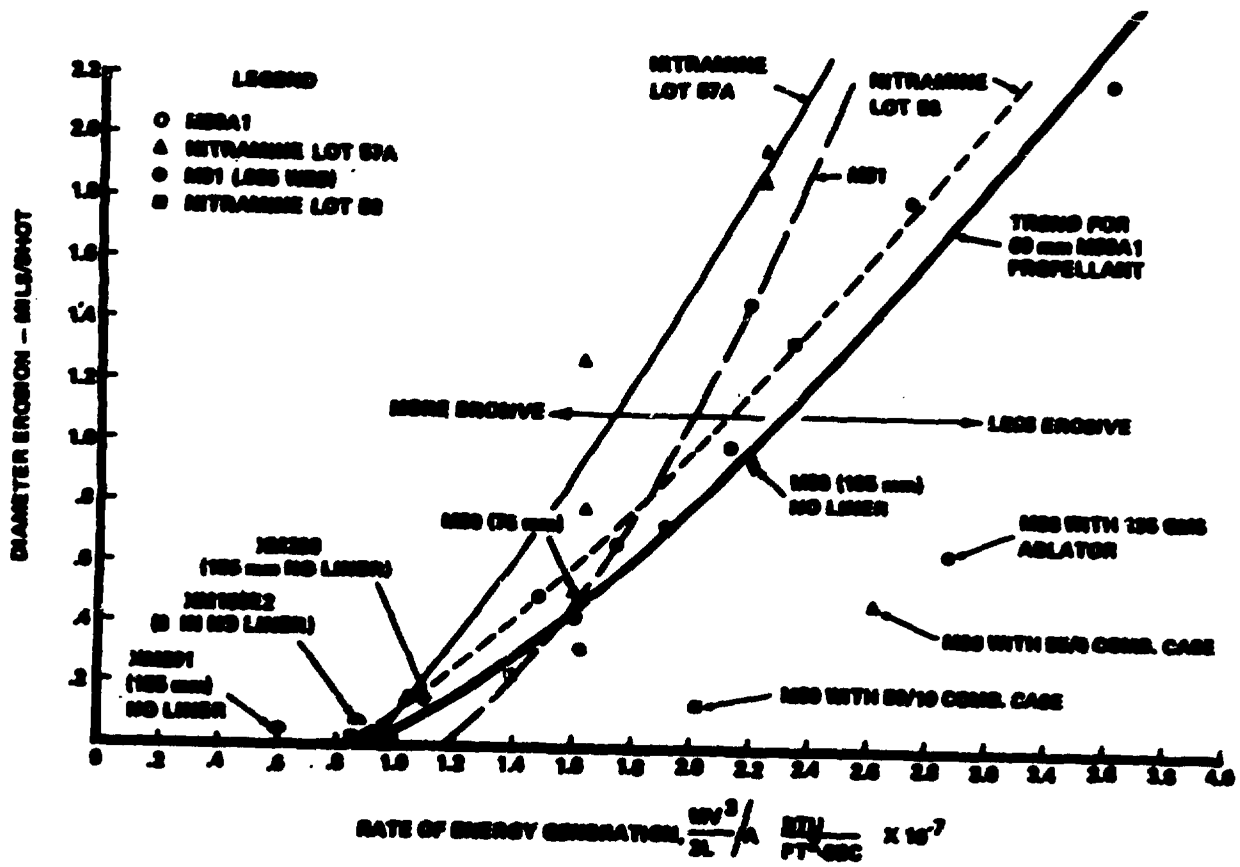

Figure 2. Erosion Correlation (from Reference 5).

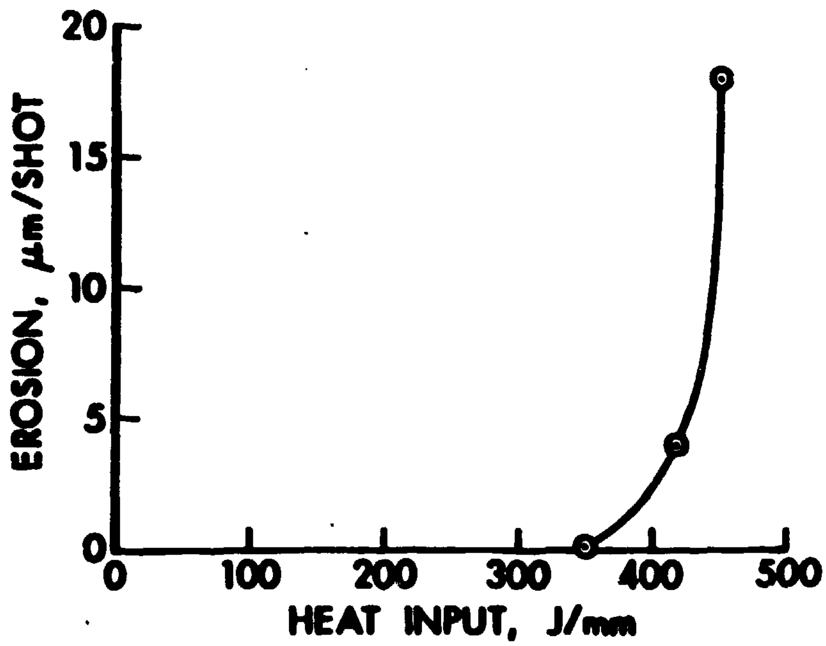

Figure 3. Heat Input vs. Erosion for APDS Rounds in 105 mm Tank Cannon (from Reference 6).

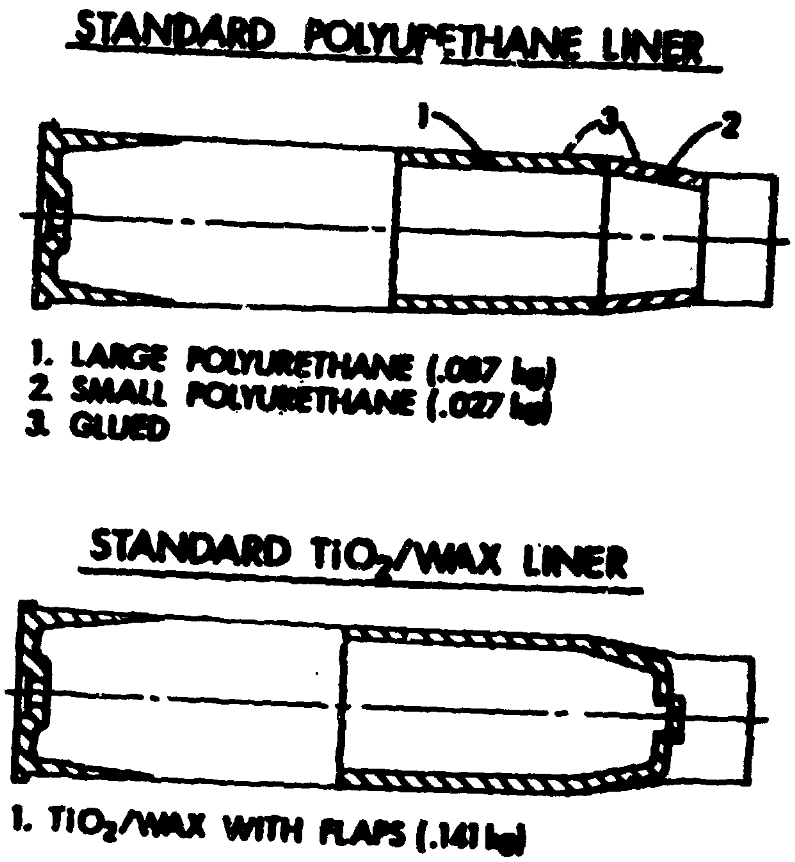

Figure 4. Configuration of Wear-Reducing Additives (from Reference 6).

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